REVIEW

Intake of Palm Olein and Lipid Status in Healthy Adults: A Meta-Analysis

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ABSTRACT

It is not clear whether a saturated fatty acid–rich palm olein diet has any significant adverse effect on established surrogate lipid markers of cardiovascular disease (CVD) risk. We reviewed the effect of palm olein with other oils on serum lipid in healthy adults. We searched in MEDLINE and CENTRAL: Central Register of Controlled Trials from 1975 to January 2018 for randomized controlled trials of ≥2 wk intervention that compared the effects of palm olein (the liquid fraction of palm oil) with other oils such as coconut oil, lard, canola oil, high-oleic sunflower oil, olive oil, peanut oil, and soybean oil on changes in serum lipids. Nine studies were eligible and were included, with a total of 533 and 542 subjects on palm olein and other dietary oil diets, respectively. We extracted and compared all the data for serum lipids, such as total cholesterol (TC), LDL cholesterol, HDL cholesterol, triglyceride, and TC/HDL cholesterol ratio. When comparing palm olein with other dietary oils, the overall weighted mean differences for TC, LDL cholesterol, HDL cholesterol, triglycerides, and the TC/HDL cholesterol ratio were −0.10 (95% CI: −0.30, 0.10; $P = 0.34$), −0.06 (95% CI: −0.29,0.16; $P = 0.59$), 0.02 (95% CI: −0.01, 0.04; $P = 0.20$), 0.01 (95% CI: −0.05, 0.06; $P = 0.85$), and −0.15 (95% CI: −0.43, 0.14; $P = 0.32$), respectively. Overall, there are no significant differences in the effects of palm olein intake on lipoprotein biomarkers ($P > 0.05$) compared with other dietary oils. However, dietary palm olein was found to have effects comparable to those of other unsaturated dietary oils (monounsaturated fatty acid– and polyunsaturated fatty acid–rich oils) but differed from that of saturated fatty acid–rich oils with respect to the serum lipid profile in healthy adults. *Adv Nutr* 2019;10:647–659.

Keywords: meta-analysis, lipid profile, palm olein, saturated fatty acid, healthy adults

Introduction

According to the WHO, cardiovascular disease (CVD) is the leading cause of death globally. Diets high in saturated fat, resulting in increased serum lipid concentrations, are a major contributor to CVD (1, 2). Increased LDL cholesterol concentrations have been shown to increase the risk of CVD (3). Saturated fat intake has also been extensively discussed as one of the main reasons for dyslipidemia, a clinical problem associated with CVD (4). However, recent systematic reviews demonstrated that the consumption of saturated fats in the diet did not lead to a significant reduction in CVD (5–12), and dairy saturated fats might even be cardioprotective (13). A study by Sacks et al. (14) reported that replacing SFAs with PUFAs lowers the risk of CVD, but noted that excessive amounts of PUFAs might be detrimental to antioxidant-compromised individuals (15). Clearly, our knowledge on the effects of SFAs on CVD risk is at present neither final nor complete.

Palm oil is a unique vegetable oil as it has almost equal amounts of SFAs (mainly palmitic acid 44–45%) and unsaturated fatty acids (oleic acid 39–40%; linoleic acid 10–11%). The low percentage of linoleic acid makes palm oil more stable against oxidative deterioration during food preparation. Palm oil is semisolid at room temperature (25–30°C) and can be fractionated into palm olein (liquid fraction) and palm stearin (solid fraction).

Palm olein contains higher levels of total oleic acid (39–45%) and linoleic acid (10–13%) compared with palm oil (16). Physically, it is clear and colorless at 25°C. It can be fractionated further to produce palm super olein which has even higher levels of oleic and linoleic acids, resulting in higher iodine values (IVs) of >60. Further fractionation of

palm super olein produces palm top olein (IV 70–72). Palm olein with IV <60 has a cloud point of 6–10°C, whereas palm top olein (IV 70–72) has a cloud point <0°C. Therefore, palm oleins with higher IVs are produced for temperate countries as such oils can remain clear in colder environments. Despite having differences in IVs, all oleins are suitable for cooking. Hence, these oleins (palm olein, palm super olein, palm top olein) are usually referred to as the liquid fraction of palm oil or just as "palm olein" in general.

Palm oil has increasingly been used as an alternative to partially hydrogenated fats (17). However, there are serious concerns that palm oil is not nutritionally ideal and that the intake of palm oil has negative effects on lipid profiles due to its high SFA content. In recent years, palm oil use in humans has been reviewed, (2, 18), but the effect of palm olein as a whole has not been discussed. Palm oil and its fractions are considered very versatile fats, having physical and chemical properties suited to a wide range of food and nonfood applications [**Figure 1**, **Supplemental Table 1** (**Supplemental References 1–2**)]. In addition, many products can be obtained from both natural and industrially modified palm oil. For example, palm stearin, the solid fraction of palm oil (containing 52.9–82.5% saturated fat), is normally used as hardstock and is blended with other oils to manufacture margarine, shortening, and confectionery products, but is never used as a cooking oil. Therefore, it is important to study the effect of palm olein, which is commonly used as a household cooking oil in Southeast Asia and sub-Saharan Africa. The aim of this meta-analysis was to provide an objective comparison on the effect of palm olein with other cooking oils, without any interference from other palm oil fractions, modified fats, and blended oils in healthy adults who represent the majority of general populations. We aimed to investigate the effect of palm olein on serum total cholesterol (TC), LDL cholesterol, HDL cholesterol, TGs, and the TC/HDL cholesterol ratio in healthy adults.

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Author disclosures: PTV and YTN are research officers in the Nutrition Unit of the Malaysian Palm Oil Board (MPOB), which is a government-owned research institution. STL is a postgraduate student from the Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, Malaysia. XSY is a postgraduate student from the Faculty of Biotechnology and Biomolecular Sciences, University Putra Malaysia, Malaysia. TKWN was the former head of the Cardiovascular, Diabetes, and Nutrition Research Centre, Institute for Medical Research, Kuala Lumpur, Malaysia, and is currently an Associate Professor at the Department of Biomedical Science, Faculty of Science, Universiti Tunku Abdul Rahman (UTAR), Kampar, Perak, Malaysia. VKML is the consultant family physician in the International Medical University (IMU) Medical Clinic, Kuala Lumpur and Associate Professor in the Department of Family Medicine, School of Medicine, IMU Clinical Campus in Seremban, Malaysia. ASHO is the chairman of the Malaysia Oil Scientists' and Technologists' Association (MOSTA), Petaling Jaya, Selangor, Malaysia. All authors have no commercial interests to declare. The supporting agency played no role in the design, data analysis, or interpretation of the study.
Supplemental Table 1, Supplemental References, Supplemental Figures 1–6, and Supplemental Materials 1–3 are available from the "Supplementary data" link in the online posting of the article and from the same link in the online table of contents at https://academic.oup.com/advances.
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Abbreviations used: CAN, canola oil; CO, coconut oil; CVD, cardiovascular disease; HOS, high oleic sunflower oil; IV, iodine value; L, lard; OO, olive oil; PE, peanut oil; RCT, randomized controlled trial; SBO, soybean oil; TC, total cholesterol.

Methods

We searched all published human feeding studies that used randomized controlled trials (RCTs) and fulfilled all of the following criteria: *1*) original data for dietary interventions using palm olein rich–diets or reported as "palm oil" diets. The percentage energy of the palm olein–rich diets was calculated based on the diet formulation and the palm olein IV ranges, i.e. IV <60, IV 60–69, or IV 70–72. Palm olein IV <60 contains 36.8–43.2% palmitic acid and 39.8–44.6% oleic acid; palm olein IV 60–69 contains 30.1–37.1% palmitic acid and 43.2–49.2% oleic acid; and palm olein IV 70–72 contains an average of 28.8% palmitic acid and 52.0% oleic acid (16); *2*) the intervention period must be ≥2 wk duration; *3*) the mean values of the lipid profile, i.e. TC, LDL cholesterol, HDL cholesterol, TGs, or TC/HDL cholesterol were reported; and *4*) study participants were adult men or women (aged 18–65 y) with no chronic diseases, representing the general healthy populations. We excluded interventions that used *1*) crude palm oil or red palm olein; *2*) modified oil, e.g., chemically interesterified, enzymatically interesterified, or hydrogenated palm oils; *3*) palm oil blended with any other oils; *4*) palm oil fractions such as palm kernel oil, palm stearin, and palm mid fraction that were incorporated as test fats.

Search strategy

The search was conducted with the use of the standard Cochrane procedures. We searched published articles from 1975 (when palm oil refining and fractionation facilities were established and widely expanded) to January 2018, through MEDLINE (http://www.ncbi.nlm.nih.gov/pubmed) and CENTRAL (Central Register of Controlled Trials; http://www.cochranelibrary.com/) for randomized controlled feeding trials of palm olein. Combinations of the following keywords were used: palm oil, palm olein, cholesterol, triglyceride, triacylglycerol, lipoprotein, clinical trial, and humans. From the selected articles, we also searched the reference lists to identify potential articles not generated in the databases.

Keywords and MeSH terms for search strategy

(("palm oil"[Supplementary Concept] OR "palm oil"[All Fields]) OR (palm[All Fields] AND olein[All Fields])) AND (("cholesterol"[MeSH Terms] OR "cholesterol"[All Fields]) OR ("triglycerides"[MeSH Terms] OR "triglycerides"[All Fields] OR "triglyceride"[All Fields]) OR ("triglycerides"[MeSH Terms] OR "triglycerides"[All Fields] OR "triacylglycerol"[All Fields]) OR ("lipoproteins"[MeSH Terms] OR "lipoproteins"[All Fields] OR "lipoprotein"[All Fields])) AND (Clinical Trial [ptyp] AND "humans"[MeSH Terms]) for the MEDLINE search; (palm oil OR palm olein) AND (cholesterol OR triglyceride OR triacylglycerol OR lipoprotein) for the Cochrane Library search.

Selection of studies

All abstracts and full-text articles were evaluated based on the inclusion and exclusion criteria by 4 investigators (PTV, STL, YTN, and XSY) independently. Technical consultations

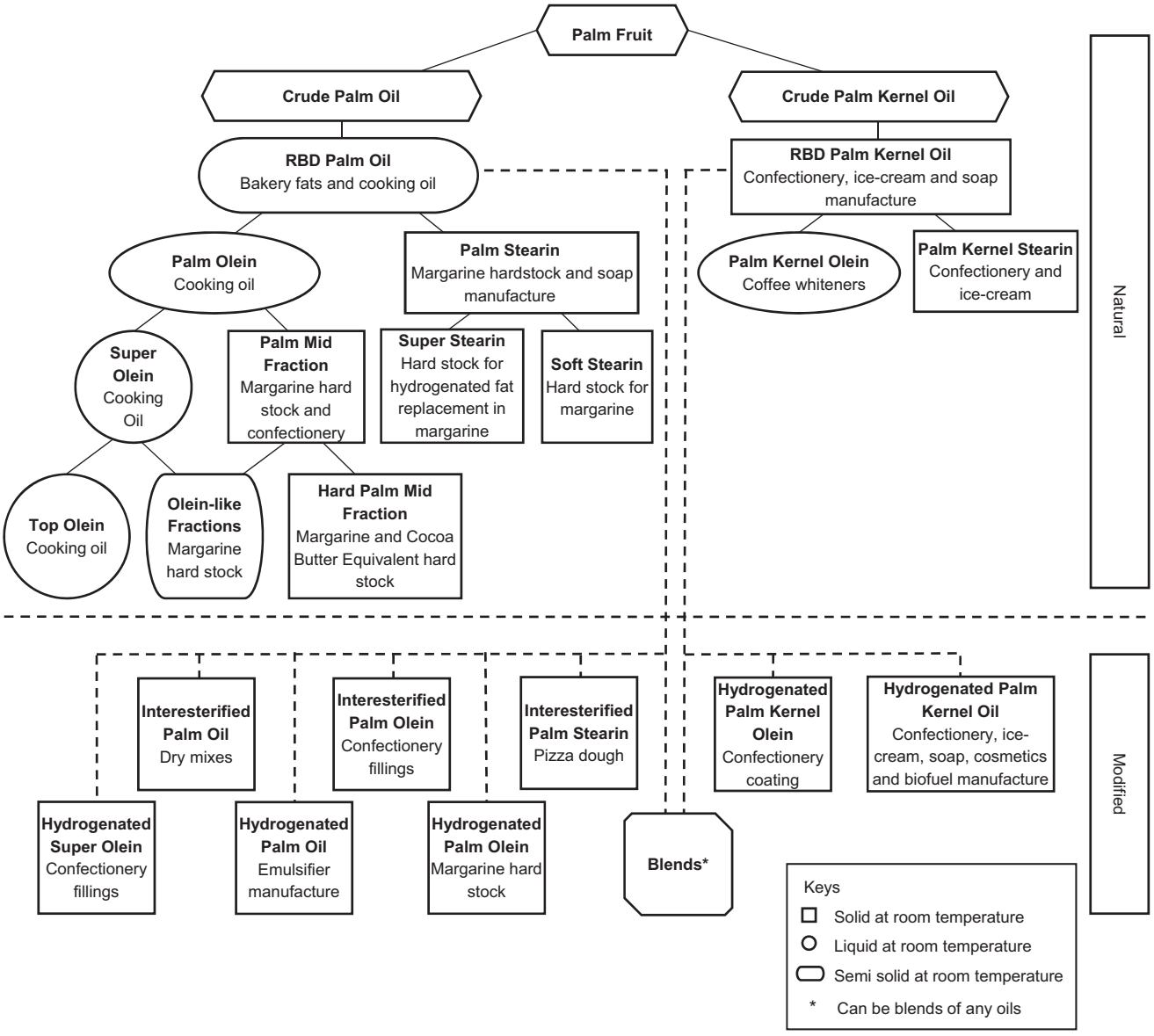

FIGURE 1 The versatility of palm oil and its fractions in food and nonfood applications. RBD, refined, blended, deodorized.

with 3 other investigators (TKWN, VKML, and ASHO) were sought and any disagreement was resolved by consensus. In the process, we removed any duplicate papers.

Data collection and quality assessment

We extracted information on authors, publication year, characteristics of the subjects (gender, age, and health condition), drop-out rates, study designs (crossover or parallel, single or double blind), duration of feeding, use of run-in or wash-out periods, oils used as interventions and comparisons (type, fatty acid composition, energy percentage), the lipid profile changes, along with the corresponding SE, SD and 95% CI values. We tabulated the results in 2 different entries when the genders were reported separately.

Risk of bias was assessed with the Cochrane risk-of-bias tool. The following criteria were used: sequence generation (selection bias), allocation concealment (selection bias), blinding of participants and personnel (performance bias), blinding of outcome assessment (detection bias), incomplete outcome data (attrition bias), selective reporting (reporting bias), and others (funding, etc.). For each criterion, risk of bias was classified into low, unclear, or high for each study. (**Supplemental Figure 1**A, B). Publication bias was also assessed with the use of funnel plots.

Statistical analysis

For the purpose of statistical analysis, we classified the comparison test diets into 2 groups: *1*) diet rich in palm olein, and *2*) diet rich in other oils. Subgroup analyses comparing diets rich in palm olein with diets rich in oils containing SFAs, MUFAs and PUFAs were also conducted. We standardized and converted all the reported mean values of TC, LDL

cholesterol, HDL cholesterol, and TGs into mmol/L prior to analyses.

We used Review Manager 5.3 to perform the statistical analyses. Means, sample sizes, and the corresponding SE, SD, or 95% CI were used as data inputs. We reported the weighted mean differences in blood lipid levels between the palm olein diet and other oil diets tested.

We used a fixed-effect model and assessed the heterogeneity between studies through the use of the chi-square test for homogeneity, defining significant heterogeneity as $P < 0.1$. We quantified the heterogeneity according to the I^2 statistic, which represents the percentage of total variation across studies that is attributable to heterogeneity rather than to chance. We considered an I^2 of >75% as high heterogeneity, 50–75% as moderate heterogeneity, and <50% as low heterogeneity (19). If the I^2 is high, we performed and reported the meta-analysis with the use of a random-effect model.

Results

Figure 2 shows the results of the literature search and screening as per Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (20). We had identified an initial total of 185 published articles from our search, of which 77 were duplicates. Full-text reading excluded 88 articles, with 20 articles remaining for further evaluation. Final screening to ascertain that the liquid fraction of palm oil, namely palm olein, was used excluded another 13 articles that used the nonliquid fraction. We identified 2 citations that fulfilled our criteria from the reference lists of the selected studies; hence we had a final number of 9 eligible studies that fulfilled all our criteria for the meta-analysis.

In this review, we compared the serum lipid profile of healthy adults fed with SFA-rich palm olein with other oils including animal fat [lard (L)] and various plant fats: SFA-rich oil [coconut oil (CO)], MUFA-rich oils [canola oil (CAN), high oleic sunflower oil (HOS), olive oil (OO) and peanut oil (PE)], and PUFA-rich oils [soybean oil (SBO and sunflower oil (SUN)]. We analyzed 9 studies with a total of 533 subjects fed on palm olein and 542 subjects on other oils. Four studies were conducted in Malaysia (21–24), 2 studies in China (25, 26), and 1 study each in Australia (27), Finland (28), and Colombia (29) from 1991 to 2017. Six studies used the crossover design in their interventions and 3 studies—Choudhury et al. (27), Zhang et al. (25), and Lucci et al. (29)—used parallel design. All subjects were healthy adults with no reported prior illness, during or at completion of the studies. Their ages ranged from 18 to 64 y. The duration of the dietary interventions for each test fat varied from 4 to 12 wk.

Table 1 shows the study designs and baseline characteristics of the 9 studies. The effects of palm olein diet were

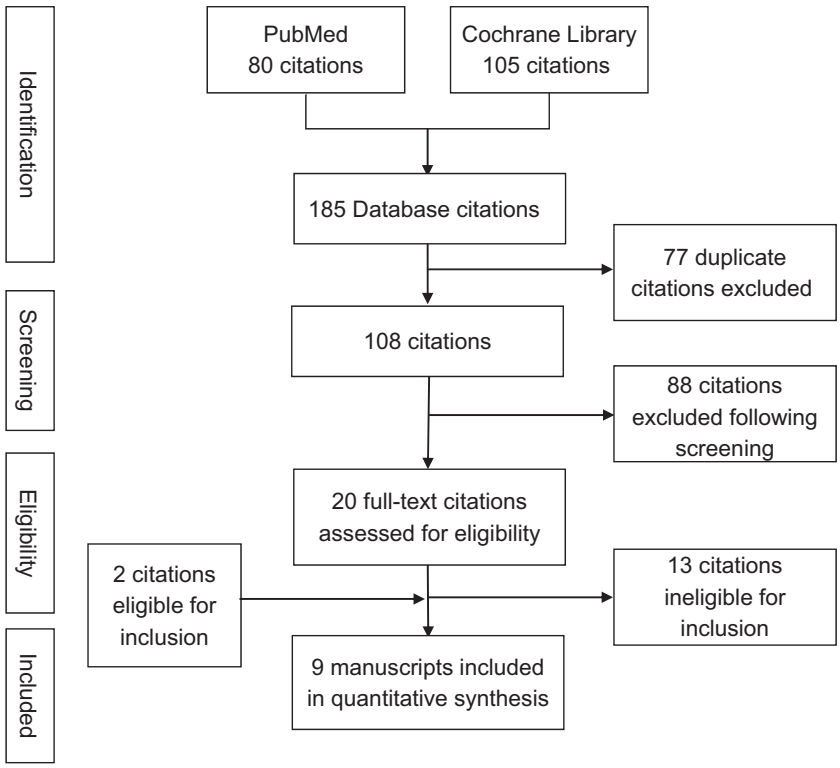

FIGURE 2 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow chart of study selection (updated to January 2018). Two citations were found eligible for inclusion: *1*) Lucci et al. 2016 (29) was not available using the keyword search but was published and available in PubMed; *2*) Sun et al. 2017 (26) was published online but was not available in PubMed during the searches. PubMed: 80 citations (**Supplemental Material 1**); Cochrane Library: 105 citations (**Supplemental Material 2**); and excluded papers: 101 citations (**Supplemental Material 3**).

TABLE 1 Study designs and baseline characteristics of subjects[1]

Study (ref.), country	Design	Type of oil	Total fat (% energy)	Test fat intake/total fat	*n*	Mean age, y	Body weight, kg	BMI, kg/m^2[2]	Baseline lipid Profile				
									TC, mmol/L	LDL-C, mmol/L	HDL-C, mmol/L	TG, mmol/L	Duration, wk
Ng et al. (21), Malaysia	RCT	Palm olein	30	>2/3	27	24.0 ± 3.1	53.4 ± 8.7	19.5 ± 2.0	4.4 ± 0.8	2.9 ± 0.8	1.1 ± 0.3	1.0 ± 0.3	5
	Dietary sequence Double blind	CO											
Ng et al. (22), Malaysia	RCT	Palm olein	34	>2/3	20 (M)	30.0 ± 4.5	NR	22.3 ± 2.8	5.0 ± 0.7	3.5 ± 0.6	0.9 ± 0.2	1.2 ± 0.7	6
	Crossover Blinding NR	CO OO			13 (F)	26.6 ± 3.9	NR	21.6 ± 3.4	4.9 ± 0.8	3.4 ± 0.7	1.2 ± 0.2	0.8 ± 0.4	
Choudhury et al. (27), Australia	RCT	Palm olein	30–31	<2/3	10 (M)	27.9 ± 9.0	66.9 ± 11.1	24.2 ± 1.2	5.5 ± 1.1[2]	3.6 ± 1.4[2]	1.3 ± 0.6[2]	1.2 ± 0.5[2]	4.3
	Crossover Blinding NR	OO			11 (F)	27.7 ± 7.8	65.3 ± 11.5	23.9 ± 3.2					
Zhang et al. (25) China	RCT	Palm olein	30	>2/3	120	18–25	NR	NR	NR	NR	NR	NR	6
	Parallel Blinding NR	SBO PE L											
Vega-López et al. (28), Finland	RCT	Palm olein	30	>2/3	15	63.9 ± 5.7	NR	26.0 ± 2.4	6.5 ± 0.8	4.6 ± 0.8	1.4 ± 0.3	1.3 ± 0.4	5
	Crossover Blinding NR	SBO CAN											
Voon et al. (24), Malaysia	RCT	Palm olein	30	>2/3	45	30.1 ± 8.3	NR	23.1 ± 3.7	4.7 ± 0.7	3.1 ± 0.6	1.2 ± 0.3	1.0 ± 0.4	5
	Crossover Single blind	OO CO											
Filippou et al. (23), Malaysia	RCT	Palm olein	27	>2/3	10 (M)	28.6 ± 6.3	68.2 ± 7.3	23.8 ± 3.0	5.3 ± 0.7	3.7 ± 0.7	1.2 ± 0.2	1.0 ± 0.3	6
	Crossover Single blind	HOS			31 (F)	29.3 ± 8.0	54.0 ± 8.1	22.7 ± 3.0	4.8 ± 0.7	2.9 ± 0.5	1.5 ± 0.3	0.8 ± 0.4	
Lucci et al. (29), Colombia	RCT	Palm olein	25 mL/d + usual diet	25 mL/d + usual diet	160	63.5 ± 7.2	NR	28.3 ± 3.8	5.3 ± 1.0	3.1 ± 1.0	1.2 ± 0.3	2.5 ± 1.4	12.8
	Parallel Blinding NR	OO											
Sun et al. (26), China	RCT	Palm olein	30	≤2/3	48	39.2 ± 10.0	NR	22.4 ± 2.2	4.3 ± 0.6	2.5 ± 0.4	1.2 ± 0.2	0.9 ± 0.3	5
	Crossover Double blind	OO			52	41.3 ± 8.4		22.0 ± 1.9	4.4 ± 0.6	2.6 ± 0.4	1.2 ± 0.2	0.9 ± 0.3	

[1] Mean values ± SDs. CAN, canola oil; CO, coconut oil; F, female; HDL-C, HDL cholesterol; HOS, high oleic sunflower oil; L, lard; LDL-C, LDL cholesterol; M, male; NR, not reported; OO, olive oil; PE, peanut oil; RCT, randomized controlled trial; SBO, soybean oil.

[2] The values reported were mean values for both male and female as reported.

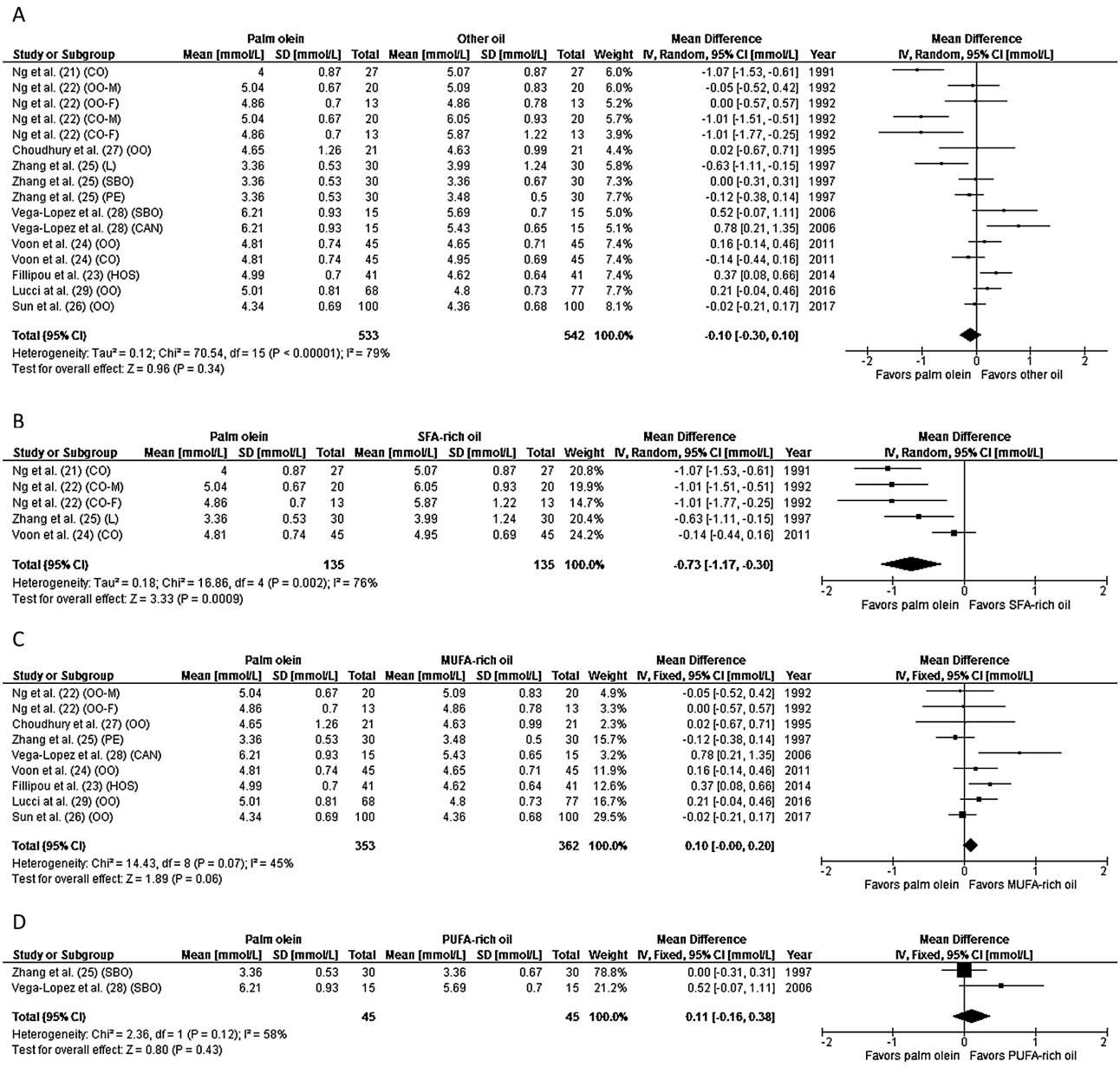

FIGURE 3 Forest plot showing the effect of palm olein on serum TC compared with other oils (A), SFA-rich oil (B), MUFA-rich oil (C), or PUFA-rich oil (D) in healthy adults. CAN, canola oil; CO, coconut oil; F, female; HOS, high oleic sunflower oil; L, lard; M, male; OO, olive oil; PE, peanut oil; SBO, soybean oil.

compared to those of other oils such as CO in *1*) Ng et al. (21); CO and OO in *2*) Ng et al. (22) and *3*) Voon et al. (24); OO in *4*) Choudhury et al. (27), *5*) Lucci et al. (29), and *6*) Sun et al. (26); SBO, PE, and L in *7*) Zhang et al. (25); SBO and CAN in *8*) Vega-López et al. (28); and HOS in *9*) Filippou et al. (23). All 9 studies (21–29) reported TC, LDL cholesterol, HDL cholesterol, and TG values, but only 5 studies (23–25, 28, 29) reported the TC/HDL cholesterol ratio.

Figure 3A shows forest plot for the effect of palm olein compared with other oils on TC. Five comparisons [Ng et al. (21) (CO); Ng et al. (22) (CO males); Ng et al. (22) (CO females); Zhang et al. (25) (L); Vega-López et al. (28) (CAN)] show a statistically significant difference in mean TC. Four studies show that subjects on palm olein were reported to have statistically significantly lower TC than those on SFA-rich oils. Other comparisons do not demonstrate any significant difference. This set of data shows high heterogeneity ($I^2 = 79\%$). The overall weighted mean difference in TC is −0.10 (95% CI: −0.30, 0.10; $P = 0.34$). A subgroup analysis of TC comparing palm olein with SFA-rich fat is shown in Figure 3B. The mean difference in TC comparing palm olein with SFA-rich oil was statistically significant, being lower by −0.73 (95% CI: −1.17,

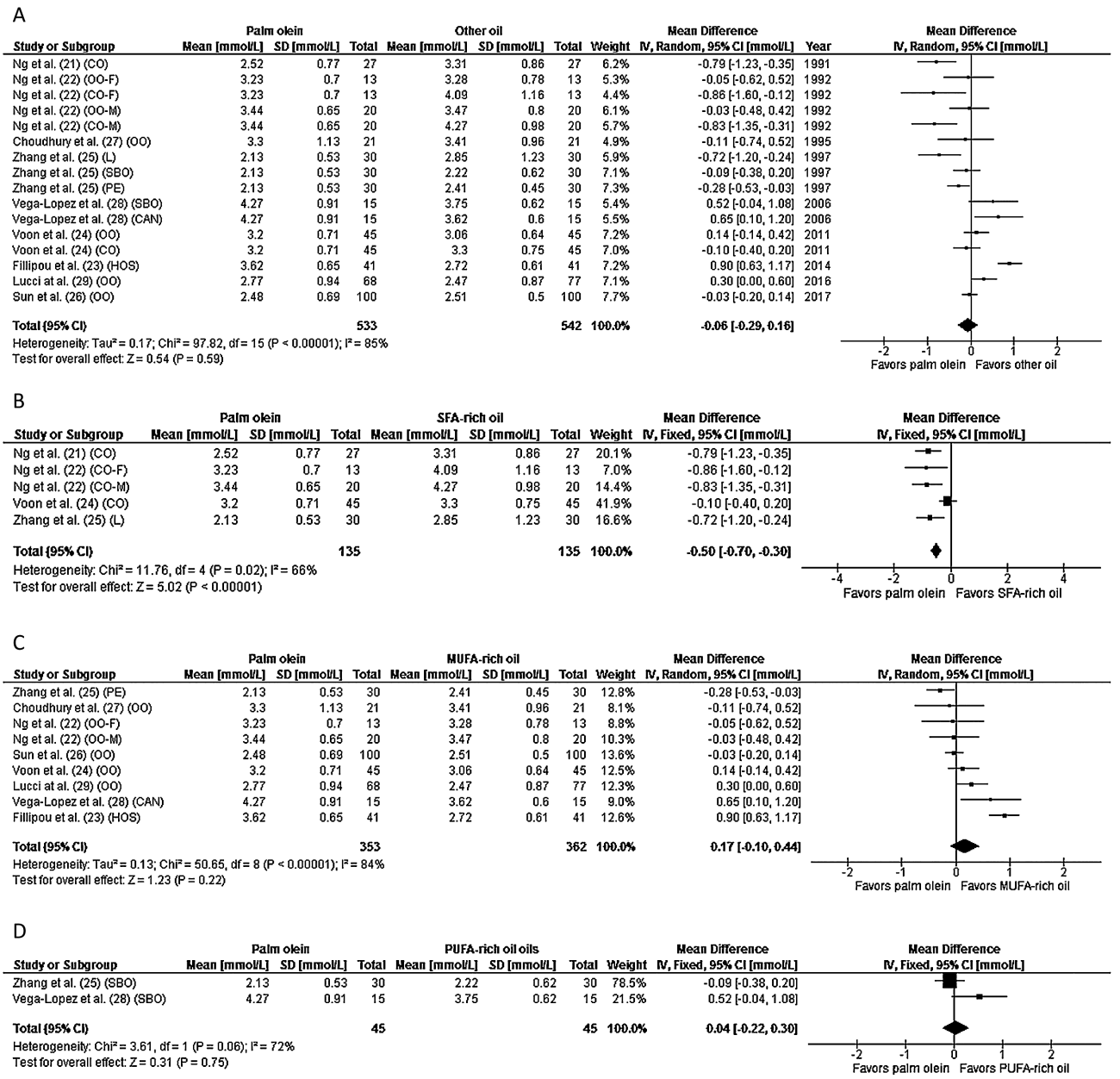

FIGURE 4 Forest plot showing the effect of palm olein on serum LDL cholesterol compared with other oils (A), SFA-rich oil (B), MUFA-rich oil (C), or PUFA-rich oil (D) in healthy adults. CAN, canola oil; CO, coconut oil; F, female; HOS, high oleic sunflower oil; L, lard; M, male; OO, olive oil; PE, peanut oil; SBO, soybean oil.

−0.30; $P = 0.0009$). However, subgroup analyses of TC comparing palm olein with MUFA- and PUFA-rich oils show no significant differences ($P = 0.06$ and 0.43, respectively) (Figure 3C, D).

Figure 4A shows the effect of palm olein and other oils on LDL cholesterol. The overall weighted mean difference in LDL cholesterol is −0.06 (95% CI: −0.29, to 0.16; $P = 0.59$). This analysis has a high heterogeneity ($I^2 = 85\%$). Seven comparisons [Ng et al. (21) (CO); Ng et al. (22) (CO males); Ng et al. (22) (CO females); Zhang et al. (25) (PE); Zhang et al. (25) (L); Vega-López et al. (28) (CAN); Filippou et al. (23) (HOS)] show statistically significant differences, with 5 comparisons favoring palm olein. Other comparisons do not show any significant differences in LDL cholesterol. Subgroup analyses comparing the effect of palm olein with SFA-, MUFA-, and PUFA-rich diets are shown in Figure 4B–D. Overall, subjects on palm olein were found to have a lower mean LDL cholesterol of −0.50 (95% CI: −0.70, to −0.30; $P < 0.00001$) compared with subjects on other SFA-rich oils. However, no difference in LDL cholesterol was found when comparing palm olein with MUFA- and PUFA-rich diets (Figure 4C, D).

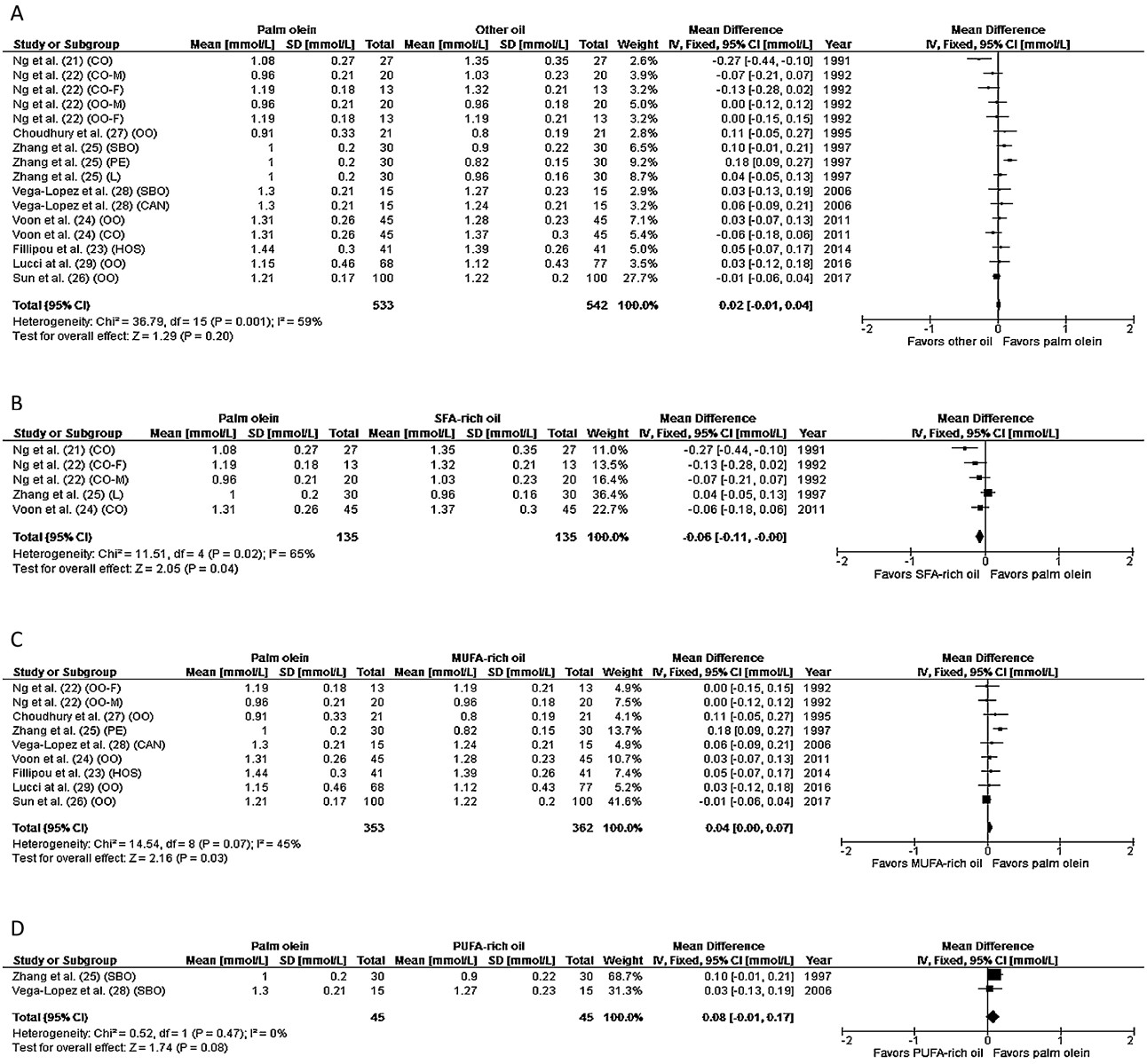

FIGURE 5 Forest plot showing the effect of palm olein on serum HDL cholesterol compared with other oils (A), SFA-rich oil (B), MUFA-rich oil (C), or PUFA-rich oil (D) in healthy adults. CAN, canola oil; CO, coconut oil; F, female; HOS, high oleic sunflower oil; L, lard; M, male; OO, olive oil; PE, peanut oil; SBO, soybean oil.

Figure 5A presents the effect of palm olein compared with other oil diets on HDL cholesterol. Only 1 comparison [Ng et al. (21) (CO)] showed a significant mean difference, favoring palm olein. The overall mean difference when comparing palm olein with other oils is 0.02 (95% CI: −0.01, 0.04; $P = 0.2$, hence not statistically significant). The heterogeneity for this analysis is moderate with an I^2 of 59%. Palm olein is found to have a statistically significant lowering effect on HDL cholesterol by −0.06 (95% CI: −0.11, −0.00; $P = 0.04$) compared with SFA-rich oil (Figure 5B), which on the other hand raised HDL cholesterol by 0.04 (95% CI: 0.00, 0.71; $P = 0.03$) compared with MUFA-rich oil (Figure 5C) and showed no difference when compared with PUFA-rich oil (Figure 5D).

Figure 6A shows the effect of palm olein compared with other oil diets on TG. All 9 studies (16 comparisons) reported no significant changes in TGs. The weighted mean difference in TG was 0.01 (95% CI: −0.05, 0.06; $P = 0.85$). This set of data shows a low heterogeneity with $I^2 = 0\%$. Palm olein did not alter TG concentrations when compared with SFA-, MUFA- and PUFA-rich oils in the subgroup analyses as shown in Figure 6B–D.

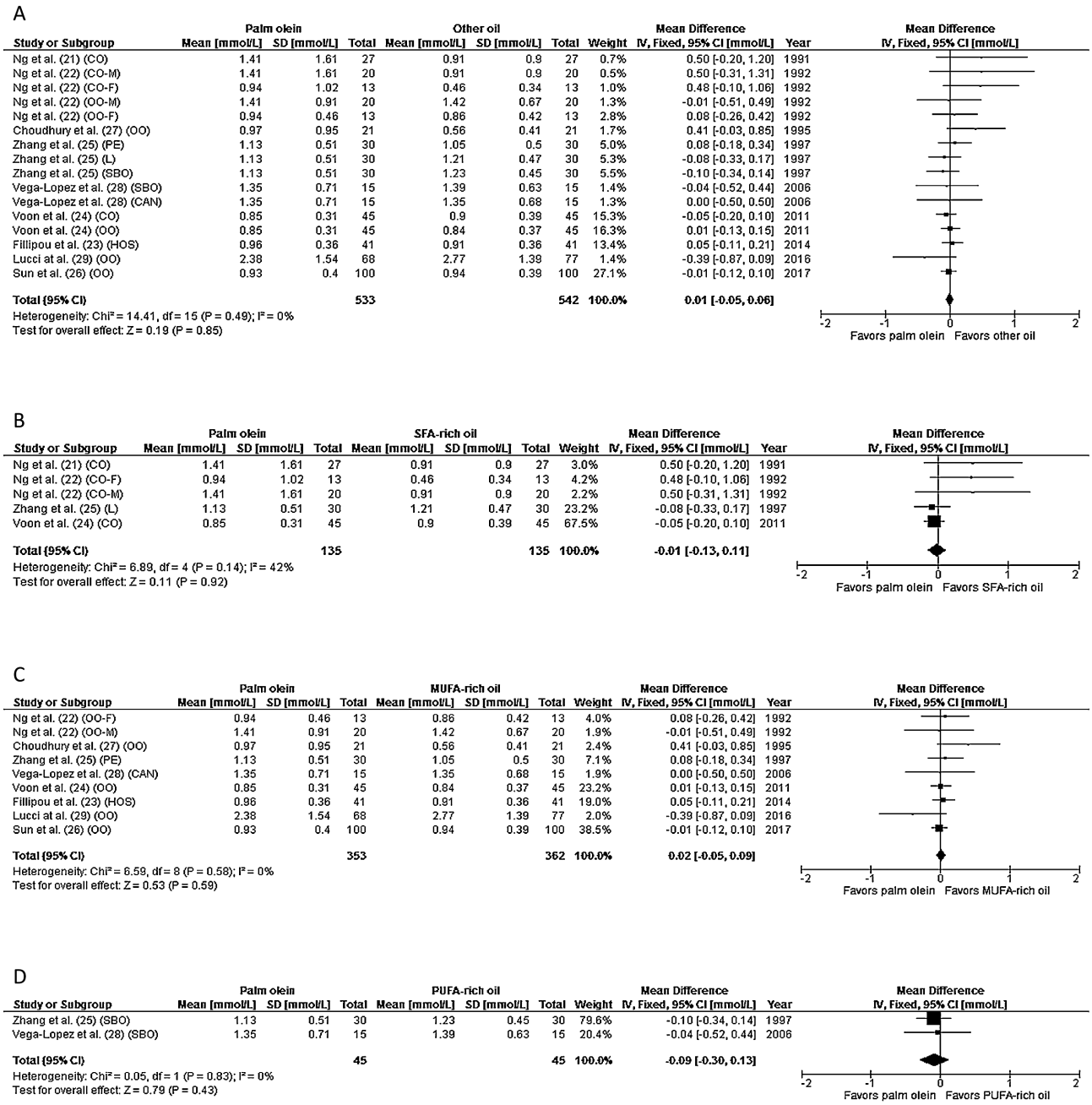

FIGURE 6 Forest plot showing the effect of palm olein on serum TGs compared with other oils (A), SFA-rich oil (B), MUFA-rich oil (C), or PUFA-rich oil (D) in healthy adults. CAN, canola oil; CO, coconut oil; F, female; HOS, high oleic sunflower oil; L, lard; M, male; OO, olive oil; PE, peanut oil; SBO, soybean oil.

Figure 7A shows that TC/HDL cholesterol ratios were reported by 5 studies (9 comparisons): Zhang et al. (25) (PE, L, and SBO), Vega-López et al. (28) (SBO and CAN), Voon et al. (24) (OO and CO), Filippou et al. (23) (HOS), and Lucci et al. (29) (OO). The overall mean difference is −0.15 (95% CI: −0.43, 0.14) in TC/HDL cholesterol, which is not statistically significant ($P = 0.32$) with $I^2 = 64\%$ indicating a moderate heterogeneity. In addition, palm olein does not affect TC/HDL cholesterol when compared with SFA-, MUFA- and PUFA-rich oils (Figure 7B–D).

Study quality of meta-evidence

We used the Cochrane risk-of-bias tool to assess the study quality. Supplemental Figure 1(A, B) shows the methodologic quality of the 9 studies. In general, all 9 studies were assessed to have low risk of selection bias, attrition bias, reporting bias, and other bias. However, there are 2 studies with unclear risk of performance bias and 4 studies with unclear risk of detection bias. Ng et al. (22) and Zhang et al. (25) did not describe the process of blinding of participants and investigators in their methodology. Detection biases were

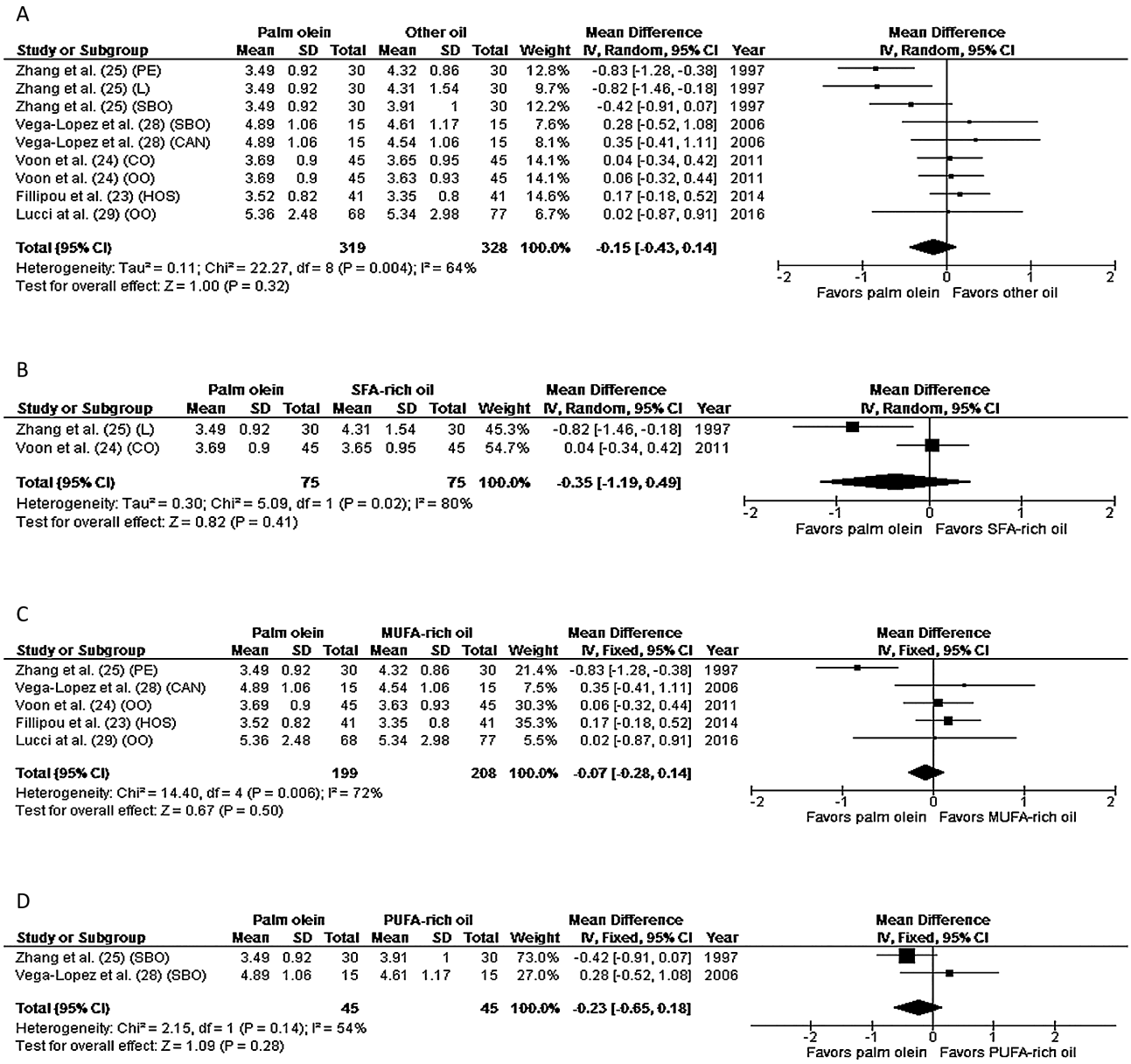

FIGURE 7 Forest plot showing the effect of palm olein on serum TC/HDL cholesterol compared with other oils (A), SFA-rich oil (B), MUFA-rich oil (C), or PUFA-rich oil (D) in healthy adults. CAN, canola oil; CO, coconut oil; F, female; HOS, high oleic sunflower oil; L, lard; M, male; OO, olive oil; PE, peanut oil; SBO, soybean oil.

unclear in Choudhury et al. (27), Lucci et al. (29), Ng et al. (22), and Vega-López et al. (28).

We also assessed possibility of publication bias (**Supplemental Figures 2**A–**6**D). We found that datasets for HDL cholesterol and TGs in the subgroup analyses comparing the effects of palm olein with SFA-, MUFA-, and PUFA-rich oils were symmetrically inverted, suggesting that publication bias was unlikely. Funnel plots were found to be asymmetric for overall TC, LDL cholesterol and TC/HDL cholesterol. This may be due to the included number of studies being small.

Sensitivity analysis was performed by excluding parallel-design (25, 29) and crossover design (21–24, 26–28) studies (**Table 2**). The results remained unchanged for all lipid markers except HDL cholesterol and TC/HDL cholesterol ratio when excluding crossover design studies. The heterogeneity (I^2) was also found not to be lowered by excluding the parallel studies. Therefore, we assumed that pooling of the 2 different designs in dietary interventions in our meta-analysis was appropriate, as there were only 2 studies that used parallel designs.

Discussion

The association between SFAs and CVD as reported in the literature is inconclusive. Recent epidemiologic evidence

TABLE 2 Sensitivity analyses comparing the differences between units of analysis that involved studies using crossover and parallel design approaches[1]

	Excluding parallel studies	Excluding crossover studies	All studies
LDL cholesterol			
P value	0.87	0.36	0.56
I^2 (%)	86	80	85
Mean difference	−0.02	−0.17	−0.06
HDL cholesterol			
P value	0.41	0.0002	0.2
I^2 (%)	39	46	59
Mean difference	−0.01	0.10	0.02
TC			
P value	0.46	0.55	0.34
I^2 (%)	82	70	79
Mean difference	−0.10	−0.09	−0.10
TG			
P value	0.53	0.35	0.85
I^2 (%)	0	3	0
Mean difference	0.02	−0.07	0.01
TC/HDL cholesterol			
P value	0.22	0.0003	0.32
I^2 (%)	0	22	64
Mean difference	0.12	−0.60	−0.15

[1] TC, total cholesterol.

found no significant difference in coronary heart disease mortality between total fat or SFA intake (30). SFAs have been reported to have an inverse association with stroke (31). Partial replacement of SFAs by *cis*-PUFAs was associated with significant CVD risk reduction. However, there was no significant risk reduction from substituting *cis*-MUFAs for SFAs. Consumption of SFA-rich dairy foods was also reported to be associated with a lower risk of ischemic stroke, but the source of SFAs was not clearly discussed (32). A recent study (14) reported that replacing SFAs from animal products (e.g., dairy and meat) with PUFAs from vegetable oil lowers CVD risk. The effect of SFAs from plant sources (e.g., palm oil, CO, cocoa butter) on CVD risk reported inconsistent findings especially with regard to palm oil (2, 18). The favorable change in blood lipids occurred when the SFA-rich palm oil was used to substitute *trans*-fatty acids (18). No difference was observed in TC/HDL cholesterol ratio when comparing palm oil with other dietary SFA-, MUFA-, and PUFA-rich oils (2, 18). On the other hand, SFAs in palm oil were reported to have similar effects on LDL cholesterol as those observed with animal fat (2). The effects of palm olein diet on lipid profile have not been discussed specifically in any meta-analysis (2, 18).

In this study, no significant differences in the lipid biomarkers tested. The positional distribution of fatty acids on the TG backbone of an edible oil might help to explain these results. SFAs (mainly palmitic acid) occupy the *sn*-1 and *sn*-3 positions of palm olein. The SFAs located at the outer stereospecific region will tend to form calcium soap and be excreted into the feces. This is due to their long chains and high melting points (60–65°C). Similar to MUFA- and PUFA-rich vegetable oils, the *sn*-2 position of palm olein is occupied predominantly by oleic acid. When ingested, oleic acid is hydrolyzed in the stomach, and absorbed intact as monoglycerides into the blood circulation (33). Therefore, a palm olein diet containing more SFAs than other liquid vegetable oils does not affect blood cholesterol and lipid profile adversely when compared with MUFA- or PUFA-rich diets. Our results suggest that palm olein does not behave like a SFA-rich fat due to its noncholesterolemic effects in healthy adults whose total fat intakes are within the recommended 30–35% of energy range. To investigate the clinical effect of palm olein, we recommend prospective cohort studies of >12 wk duration.

Strengths and limitations

This review was conducted in accordance with Cochrane standards. We obtained 185 citations in our preliminary search, checked thoroughly for duplicate data, excluded studies that used blended palm olein, and only included studies that used the liquid fraction of palm oil, palm olein; finally 9 full-text articles fulfilled our criteria. We did not apply any restriction on language in publication during the search.

This analysis has the following limitations: *1*) we only used 2 search engines to perform the searches; *2*) not all the 9 studies reported TC/HDL cholesterol ratio even though this marker was reported to be a better predictor of CVD risk; *3*) we did not compare all palm oil fractions, palm oil blends, and other modified palm oil due to the variations in physical and chemical characteristics; *4*) the study interventions were limited to a short term of 12 wk; and *5*) grey literature was not included in the search.

Conclusions

This meta-analysis concludes that diet rich in palm olein does not affect lipid profiles in healthy adults compared with other oils. Noteworthy are the comparable noninferior effects of palm olein with other unsaturated vegetable oils, namely OO, CAN, SBO, and HOS, on serum lipid profiles in healthy human adults.

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The authors' responsibilities were as follows—PTV, STL, YTN, and XSY: designed, conducted, and analyzed the systematic literature search with the use of the MEDLINE (http://www.ncbi.nlm.nih.gov/pubmed/) and Cochrane Library (http://www.cochranelibrary.com/) databases; TKWN, VKML, and ASHO: cross-checked the databases for any duplication of articles selected or for any study selected that used nonpure palm oil/palm olein; PTV, STL, YTN and XSY: wrote the manuscript; TKWN, VKML, and ASHO: were responsible for the final content check; and all authors have read and approved the final manuscript before submission.

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